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ORIGINAL PAPER

Effect of shifting cultivation on soil physical and chemical properties in Bandarban hill district, Bangladesh

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Abstract: This study reports the effects of shifting cultivation at slashing stage on soil physicochemical properties at Bandarban Sadar Upazila in Chittagong Hill Tracts of Bangladesh. At this initial stage of shifting cultivation no general trend was found for moisture content, maximum water holding capacity, field capacity, dry and moist bulk density, particle density for some chemical properties between shifting cultivated land and forest having similar soil texture. Organic matter was significantly ($p\leq$ 0.05) lower in 1-year and 3-year shifting cultivated lands and higher in 2-year shifting cultivation than in adjacent natural forest. Significant differences were also found for total N, exchangeable Ca, Mg and K and in CEC as well as for available P. Slashed area showed higher soil pH. Deterioration in land quality starts from burning of slashing materials and continues through subsequent stages of shifting cultivation.

Keywords: Chittagong Hill Tracts; natural forest; shifting cultivation; soil properties

Introduction

Topographically, Bandarban Hill District is a continuation of the Himalayan Tract. About 90% of the total area of the district is hilly, 4% covers villages, rivers and marshes, and the remaining 6% represents valley suitable for intensive agricultural production (Khisa 1998). Shifting cultivation, locally known as 'jum' is the predominant farming system in Chittagong Hill Tracts (CHTs), which in the past has been well adapted to the lives and livelihood of tribal people with little adverse effect on the ecology of the region. Increasing population pressure coupled with a shortage of suitable uplands reduced the shifting cycle from 15−20 years in 1900 to 3−5 years in the 1990s in the absence of regulations to prevent deforestation, soil erosion, biodiversity loss and environmental degradation (Gain 1998). During the fallow period, lands are left for natural regeneration with no treatment to improve fertility of the degraded land, mainly due to lack of ownership. In the conventional shifting cultivation system, sowing and weeding are done without major topsoil disturbance. Shifting cultivators broadcast smaller seeds like sesame, flower, chilli and sour leaf, and dibble relatively larger sized seeds mixed with paddy, maize, beans and cotton. After the onset of rain, seeds germinate along with numerous types of weeds. Usually, the weeds grow fast and cover the newly germinated seedlings within 2–3 weeks after sowing. Consequently, weeding becomes urgent to save the emerging crops from weed suppression and competition. Among the traditional land use systems, shifting cultivation is the oldest practice for raising agricultural crops in this hilly region of Bangladesh and became the basis of the economy of the indigenous people. This inherited shifting cultivation and forest exploitation remain central point to the traditional hill societies as their principal source of food, shelter, medicine and other products (Ahmed and Gaby 1996). Although only 2.5% of the hilly area in CHTs is used annually for shifting cultivation, other areas of similar size were used in previous years. Thus nearly all of the mountainous area of CHTs has been affected by this cultivation system and primary forest has been almost completely destroyed. The problems have been aggravated further by the use of inappropriate tillage techniques like deep ploughing on hill slopes mainly by migrants from the plain areas to grow tuber crops like arum, potato, ginger and turmeric (Tomich et al. 1998). Shifting cultivation comprises 41,485 ha or 4.3% of the total land area of CHTs and approximately two thirds or 27,530 ha of this shifting cultivated area is used for crop production (Ishaq 1971).

Several measures were taken to settle jhumias and landless

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farmers in suitably located villages in CHTs (TPR 1987). Under the rehabilitation schemes of Bangladesh Government starting from 1957, about 1.6 to 2.4 ha of forest land has been allotted to each settled cultivator (Salam et al. 2000). However, such programs could not achieve the desired level of success and suffered from inadequate participation of the target group mainly due to political unrest, lack of motivation, education, extension, infrastructure, marketing facilities and above all lack of material and financial incentives (FMP 1993). Shifting cultivation is a great concern relative to land and vegetation conservation in the south-eastern hilly watersheds of Bangladesh. Several studies (Biswas et al. 2010; Miah et al. 2010; Gafur et al. 2000, 2003; Rasul and Thapa 2003) assessed the impact of shifting cultivation on the soil environment. The present study aimed to determine the effects of shifting cultivation at the slashing stage on soil properties in Bandarban hill district. Cutting of all the naturally coming vegetation as first the step of land preparation for shifting cultivation is termed as slashing.

Materials and methods

Study area selection and soil sampling

Our study area was in Bandarban Hill District of Bangladesh (22°20′0″ N and 92°35′0″ E) where local ethnic people practice shifting cultivation or jhum for their livelihood. To select representative study sites, a preliminary survey was done in the shifting cultivated area and adjacent natural forest of Bandarban Sadar Upazila. Assistance was taken from local people and Forest Department personnel to identify study sites exposed to years of shifting cultivation yet adjacent to natural vegetation. Three paired sites were selected on mid elevation sites on hill slopes, namely 1-year shifting cultivated land at Na-mile village, 2-year shifting cultivated land at Shoalok village, and 3-year shifting cultivated land at Aat-mile village under Bandarban Sadar Upazila, each with adjacent naturally coming vegetated secondary forest. Soil samples in the shifting cultivated land and adjacent natural forest were taken at least 30 m from the boundary to avoid interaction between the two types of land use. At the time of soil sampling, shifting cultivated lands at all three locations were covered with fresh slashed materials, with the aim to dry them on exposed sun light, after which all the materials would be burnt before sowing seeds on the land as various steps of cultivation. From each land use of each paired site, nine soil samples were collected from depths of 0–15 cm with three replications during the first and second week of February 2009. Soil samples were placed in labeled, air-tight plastic bags and carried to the laboratory for analysis. For determination of bulk density, one undisturbed soil core was collected separately from the upper soil layer for each land use at each paired site.

Soil analysis

In the laboratory, soil texture of the sieved, dry soil samples was determined by the Bouyoucos hydrometer method (Huq and Alam 2005). Moisture content, maximum water holding capacity and field capacity were determined from core samples collected for bulk density. Weight of field-moist and oven-dry soil in the core was divided separately by core volume to determine bulk densities of moist and dry soil. Particle density was determined taking two 10-ml cylinders, the first filled with water up to the 10 ml mark. In the second cylinder, 2 g of soil burnt in a furnace was taken and water from the first cylinder poured until water reached the 10 ml mark. The remaining water in the first cylinder indicated volume of soil particles. The weight of soil divided by volume determined soil particle density.

Soil organic carbon and organic matter was determined by the loss on ignition method according to Ball (1964). Moist soil pH was determined using a TOA pH meter in triplicate at 1:2 soil-water ratios and total nitrogen was determined by the micro-Kjeldahl method (Jackson 1973). Exchangeable calcium and magnesium were determined by the EDTA method. Potassium concentration was quantified using a flame photometer (Jackson 1973). Cation exchange capacity (CEC) was determined after extraction with 1 N ammonium acetate solution (Black 1965). Available phosphorus was extracted with Bray and Kurtz No.2 extractant and measured by $SnCl_2$ reduced molybdophosphoric blue color method using a spectrophotometer (Jackson 1973).

Statistical analysis

Replicated data were analyzed statistically for variance and one way analysis of each parameter to determine significance level for means between two land uses using the Statistical Package SPSS 12.

Results and discussion

Soil properties

Soil texture was similar in both shifting cultivated land and adjacent natural forest at all paired sites except one site at Na-mile village (Table 1). The observed texture at both paired sites at most locations was sandy clay loam. Similar soil texture at all sites enable comparison of the effects of shifting cultivation between sites.

No general trend was found for moisture content, maximum water holding capacity, field capacity, dry and moist bulk density or particle density between shifting cultivated land and forest (Table 2). However, for most of the soil properties the values were higher in shifting cultivated land compared to adjacent natural forest, possibly because the farmed sites were covered by slashed materials. Higher soil bulk density on shifting cultivated land at all the locations was usually related to lower organic matter and compaction of soil.

Organic matter and organic carbon

Both organic matter and organic carbon were significantly ($p\leq 0.05$) lower in 1 and 3-year shifting cultivated lands and higher

in 2-year shifting cultivated land than in adjacent natural forests (Table 3). Higher value in 2 year old shifting cultivated land might be due site specific reason. At Na-mile village, organic carbon in 1-year shifting cultivated land was 2.64% and in adjacent natural forest, 3.77%. Organic matter in 3-year shifting cultivated area was 4.96% and in adjacent natural forest, 5.18% at Aat-mile village.

Table 1. Soil texture characteristics of shifting cultivated land and adjacent natural forest in Bandarban Sadar Upazila

Location	Land use	Soil particles (%)					Textural class
		Coarse sand	Fine sand	Sand	Silt	Clay	
Na-mile village	1-year shifting cultivated land	38	20	58	10	32	Sandy clay loam
	Adjacent natural forest	48	6	54	18	28	Sandy clay
Shoalok village	2-year shifting cultivated land	48	8	56	12	32	Sandy clay loam
	Adjacent natural forest	40	20	60	10	30	Sandy clay loam
Aat-mile village	3-year shifting cultivated land	46	10	56	14	30	Sandy clay loam
	Adjacent natural forest	44	12	56	12	32	Sandy clay loam

Table 2. Soil physical properties of shifting cultivated land and adjacent natural forest in Bandarban Sadar Upazila

Location	Land use	Moisture content(%)	Maximum water holding capacity (%)	Field capacity (%)	Dry bulk density (g/cm^3)	Moist bulk density (g/cm^3)	Particle density (g/cm^3)
Na-mile village	1-year shifting cultivated land	24.56 a	35.83 a	23.93 a	1.20 a	1.50 a	1.68 a
	Adjacent natural forest	27.55 a	36.30 a	28.60 a	1.08 a	1.38 a	1.55 a
Shoalok village	2-year shifting cultivated land	30.59 a	45.52 a	23.30 a	0.99 a	1.29 a	1.63 a
	Adjacent natural forest	27.35 a	40.05 a	23.24 a	1.10 a	1.39 a	1.51 a
Aat-mile village	3-year shifting cultivated land	26.03 a	41.47 a	25.31 a	1.16 a	1.46 a	1.61 a
	Adjacent natural forest	23.87 a	36.65 a	24.78 a	1.23 a	1.52 a	1.62 a

Same letter indicates no significant difference at $p \le 0.05$ for the means between two land uses.

Table 3. Soil chemical properties of shifting cultivated land and adjacent natural forest in Bandarban Sadar Upazila

Location	Land use	Soil pH	Organic C (%)	Organic matter (%)	Total N (%)	Exchangeable Ca	Exchangeable Mg	Exchangeable K	CEC	Available P ($mg \cdot kg^{-1}$ oven dry soil)
						($mmol \cdot kg^{-1}$ oven dry soil)				
Na-mile village	1-year shifting cultivated land	3.47 a	2.64 a	4.48 a	4.02 a	42.06 a	22.08 a	4.72 a	26.25	2.19 a
	Adjacent natural forest	4.17 a	3.77 b	6.49 b	3.48 a	43.43 a	21.76 a	2.81 b	14.01	1.78 a
Shoalok village	2-year shifting cultivated land	3.83 a	3.84 a	6.60 a	2.91 a	28.88 a	18.95 a	2.91 a	11.32	1.72 a
	Adjacent natural forest	3.77 a	3.58 a	6.17 a	4.18 b	54.23 b	30.28 b	3.37 a	16.02	2.68 b
Aat-mile village	3-year shifting cultivated land	3.77 a	2.88 a	4.96 a	3.79 a	32.62 a	23.06 a	2.81 a	23.87	3.01 a
	Adjacent natural forest	3.73 a	3.01 b	5.18 b	3.09 b	10.44 b	13.70 b	3.23 a	17.65	1.85 b

Different letters indicate significant difference at $p \le 0.05$ for the means between two land uses.

Soil pH

Soil pH was slightly higher in all shifting cultivated lands than in adjacent natural forests (Table 3). At Na-mile village soil pH was 4.47 in 1-year shifting cultivated land and 4.17 in adjacent natural forest. In 3-year shifting cultivated land, soil pH was 4.77 and in adjacent natural forest 4.73 at Aat-mile village. Higher soil pH might be due to uptake of base cations in vegetated areas and reduced uptake of these cations after slashing vegetation on shifting cultivated land. Biswas et al. (2010) and Gafur et al. (2000) also found higher soil pH in shifting cultivation compared to vegetated lands in this mountainous region.

Total N

Total N content was significantly ($p \le 0.05$) higher in 3-year shifting cultivated soil and lower in 2-year shifting cultivated area than the natural forest areas (Table 3). At Na-mile village N content in 1-year shifting cultivated area was 4.02% and in adjacent natural forest contained 3.48%. In 2-year shifting cultivated area total N was 2.91% and in adjacent natural forest was 4.18% at Shoalok village. Significantly lower total N in shifting cultivated land than natural forest was also recorded by several other researchers (Biswas et al. 2012; Arunachalam 2002; Døckersmith et al. 2000). Biswas et al. (2012) found in Chittagong

Hill Tracts significantly lower total N in 2-year shifting cultivated land than natural forest. Døckersmith et al. (2000) reported that burning caused total N at soil depths of 0–2 cm to decline by 68 $kg \cdot ha^{-1}$.

Exchangeable Ca and Mg

Exchangeable Ca was significantly ($p \leq 0.05$) lower in 2-year shifting cultivated area and significantly ($p \leq 0.05$) higher in 3-year shifting cultivated area than in natural forest areas (Table 3). This parameter in 1-year shifting cultivated land was 42.06 $mmol \cdot kg^{-1}$ oven dry soil and adjacent natural forest contained 43.43 $mmol \cdot kg^{-1}$ oven dry soil at Na-mile village. In 3-year shifting cultivated area exchangeable Ca was 32.62 $mmol \cdot kg^{-1}$ oven dry soils, which was significantly higher than that of natural forest (10.44 $mmol \cdot kg^{-1}$ oven dry soil) at Aat-mile village (Table 3). Exchangeable Mg was higher in 1-year and significantly ($p \leq 0.05$) higher in 3-year and significantly ($p \leq 0.05$) lower in 2-year shifting cultivated areas than in adjacent natural forest. Exchangeable Mg in 1-year shifting cultivated area was 22.08 $mmol \cdot kg^{-1}$ oven dry soils and in adjacent natural forest 21.76 $mmol \cdot kg^{-1}$ oven dry soil at Na-mile village. In 2-year shifting cultivated area exchangeable Mg was 18.95 $mmol \cdot kg^{-1}$ oven dry soils and in adjacent natural forest was 30.28 $mmol \cdot kg^{-1}$ oven dry soils at Shoalok village (Table 3). Significantly higher available Ca and Mg in cultivated lands as compared to forested lands at most locations in the present study was in agreement with Gafur et al. (2000), who also reported an increase of the two elements in shifting cultivated soil than forested land in Banderban district. Brand and Pfund (1998) observed approximately 234 and 55 $kg \cdot ha^{-1}$ increase in Ca and Mg, respectively, after burning. Significantly lower available Ca and Mg was recorded by Biswas et al (2012) in shifting cultivated land as compared to forest in Chittagong Hill Tracts of Bangladesh.

Exchangeable K and CEC

No definite trend was found for exchangeable K and CEC between shifting cultivated area and adjacent natural forest. Exchangeable K was significantly ($p \leq 0.05$) higher in 1-year shifting cultivated area and lower in 2-year and 3-year shifting cultivated areas than in adjacent natural forests. Exchangeable K in 1-year shifting cultivated area was 4.72 $mmol \cdot kg^{-1}$ oven dry soils and in adjacent natural forest 2.81 $mmol \cdot kg^{-1}$ oven-dry soils at Na-mile village. In 2-year shifting cultivated area exchangeable K was 2.91 $mmol \cdot kg^{-1}$ oven dry soils and in adjacent natural forest 3.37 $mmol \cdot kg^{-1}$ oven-dry soils at Shoalok village (Table 3). CEC was higher in 1-year and 3-year shifting cultivated areas and lower in 2-year shifting cultivated area than in adjacent natural forests. CEC in 1-year shifting cultivated area was 26.25 $mmol \cdot kg^{-1}$ oven dry soils and in adjacent natural forest 14.01 $mmol \cdot kg^{-1}$ oven dry soils at Na-mile village. In 2-year shifting cultivated land CEC was 11.32 $mmol \cdot kg^{-1}$ oven dry soils and in adjacent natural forest 16.02 $mmol \cdot kg^{-1}$ oven dry soils at Shoalok village (Table 3). Higher CEC value in shifting cultivated area was related to higher content of Ca and Mg in shifting cultivated area compared to adjacent natural forest. In the present study lower exchangeable K in shifting cultivated land was in agreement with the findings of Biswas et al. (2012) and higher exchangeable K in agreement with Brand and Pfund (1998). Biswas et al. (2012) found lower available K in 2-year shifting cultivated land than in forest. Again, Brand and Pfund (1998) observed about 20 kg ha^{-1} increases in K after burning. That is, the content of this element also dependent on the specific site.

Available P

Available P was higher in 1-year and significantly ($p \leq 0.05$) higher in 3-year shifting cultivated and significantly ($p \leq 0.05$) lower in 2-year shifting cultivated area than in adjacent natural forest (Table 3). Available P in 1-year shifting cultivated area was 2.19 $mg \cdot kg^{-1}$ oven dry soils and in adjacent natural forest 1.78 $mg \cdot kg^{-1}$ oven-dry soil at Na-mile village. In 2-year shifting cultivated area available P was 1.72 $mg \cdot kg^{-1}$ oven dry soils and in adjacent natural forest 2.68 $mg \cdot kg^{-1}$ oven-dry soils at Shoalok village. Higher values of available P in burned soil indicated that a portion of the P contained in the aboveground biomass was transferred to soil during burning. Total P at 0–2 cm soil depth increased significantly by 6.4 $kg \cdot ha^{-1}$ after burning (Døckersmith et al. 2000). Lower available P in shifting cultivated land was recorded by Biswas et al. (2012).

Soil properties did not change greatly at the slash stage because the forested and slashed areas possessed almost similar environments. Previous studies in the same area found that subsequent stages of shifting cultivation such as burning of slashed materials, sowing, weeding and harvesting of crops cause deterioration of soil fertility with increasing cropping periods year after year (Biswas et al. 2010; Miah et al. 2010; Gafur et al. 2000, 2003).

Conclusion

Shifting cultivation practiced by ethnic people in CHTs seriously exposes soil through clearing and burning of jungles. Though shifting cultivation has many negative effects, we recorded little change at the slashing stage on soil physical and chemical properties. Shortening of the fallow period is followed by a reduction in biomass, nutrient depletion, and low productivity. The success of shifting cultivation depends on the length of the fallow period. The frequent return of farmers to the same land not only results in declining yields, but also reduces biomass production per unit area. The length of the fallow period should not be less than 10 years to have productive shifting cultivation, and this is practically impossible under the existing socioeconomic conditions in CHTs, because the per capita land area is too low.

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